Opportunities for Near Earth Object Exploration

ESMD NEO Objectives Workshop

Lindley Johnson
Program Executive
NASA HQ
10 Aug 2010

Terminology

- "Near Earth Objects (NEOs)"- any small body (comet or asteroid) passing within 1.3 Astronomical Unit (AU) of the Sun
  - 1 AU is the distance from Earth to Sun = ~ 150 million kilometers (km)
  - NEOs are predicted to pass within ~ 45 million km of Earth's orbit
  - Population of:
    - Near Earth Asteroids (NEAs)
    - Near Earth Comets (NECs) – also called Earth Approaching Comets (EACs)
      - 85 currently known
- "Potentially Hazardous Objects (PHOs)" – small body that has potential risk of impacting the Earth at some point in the future
  - NEOs passing within 0.05 AU of Earth's orbit
    - ~ 8 million km = 20 times the distance to the Moon
  - Appears to be about 20% of all NEOs discovered
- Human mission accessible objects are a subset of PHOs

NEO Observation Program

US component to International Spaceguard Survey effort

Has provided 98% of new detections of NEOs

Began with NASA commitment to House Committee on Science in May, 1998

- Averaged ~$4M/year R&A funding since 2002

Scientific Objective: Discover 90% of NEOs larger than 1 kilometer in size within 10 years (1998 – 2008)

NASA Authorization Act of 2005 provided additional direction (but no additional funding)

"…plan, develop, and implement a Near-Earth Object Survey program to detect, track, catalogue, and characterize the physical characteristics of near-Earth objects equal to or greater than 140 meters in diameter in order to assess the threat of such near-Earth objects to the Earth. It shall be the goal of the Survey program to achieve 90 percent completion of its near-Earth object catalogue within 15 years [by 2020].

NASA's NEO Search Program

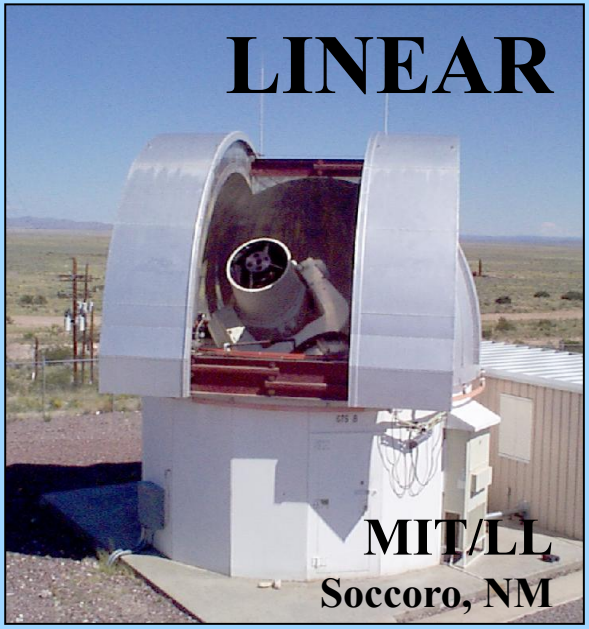
(Current Systems)

Minor Planet Center (MPC)
- IAU sanctioned
- Int'l observation database
- Initial orbit determination

www.cfa.harvard.edu/iau/mpc.html

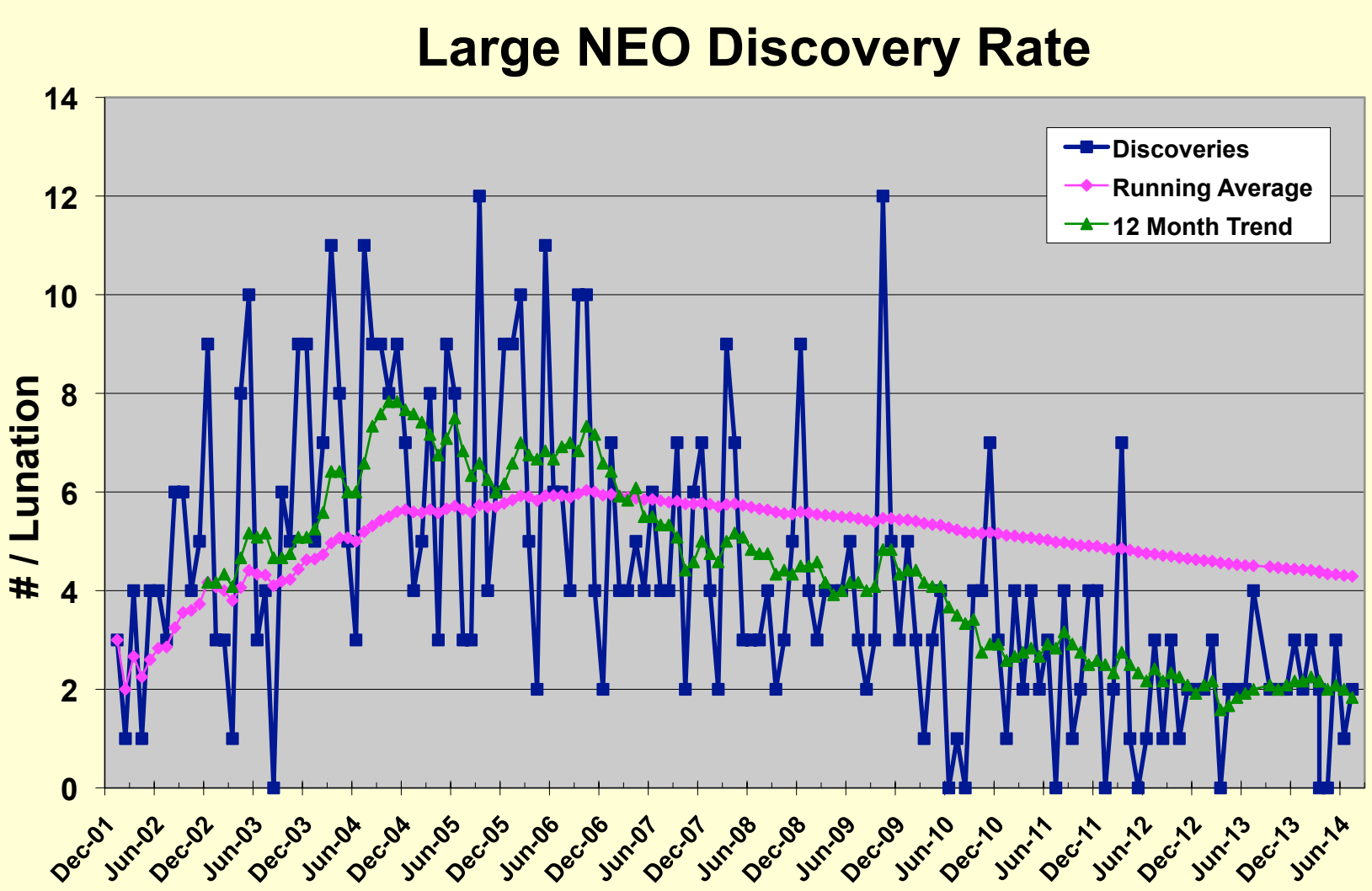
NEO Program Office @ JPL
- Program coordination
- Precision orbit determination
- Automated SENTRY

www.neo.jpl.nasa.gov

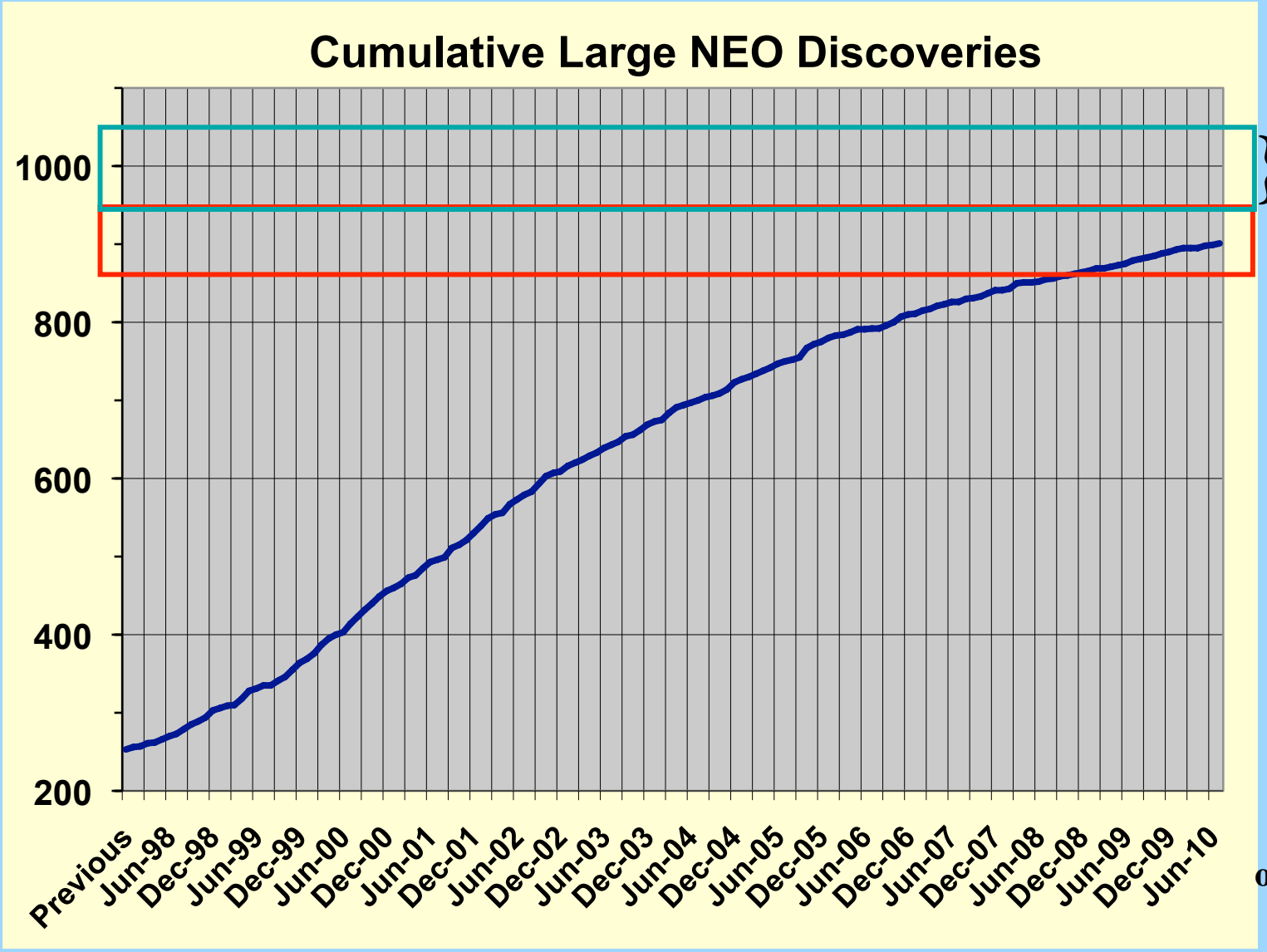


Discovery Metrics

Discovery Rate of >1km NEOs



Discovery Metrics



Estimated Population 940 - 1050

Goal 850 - 940

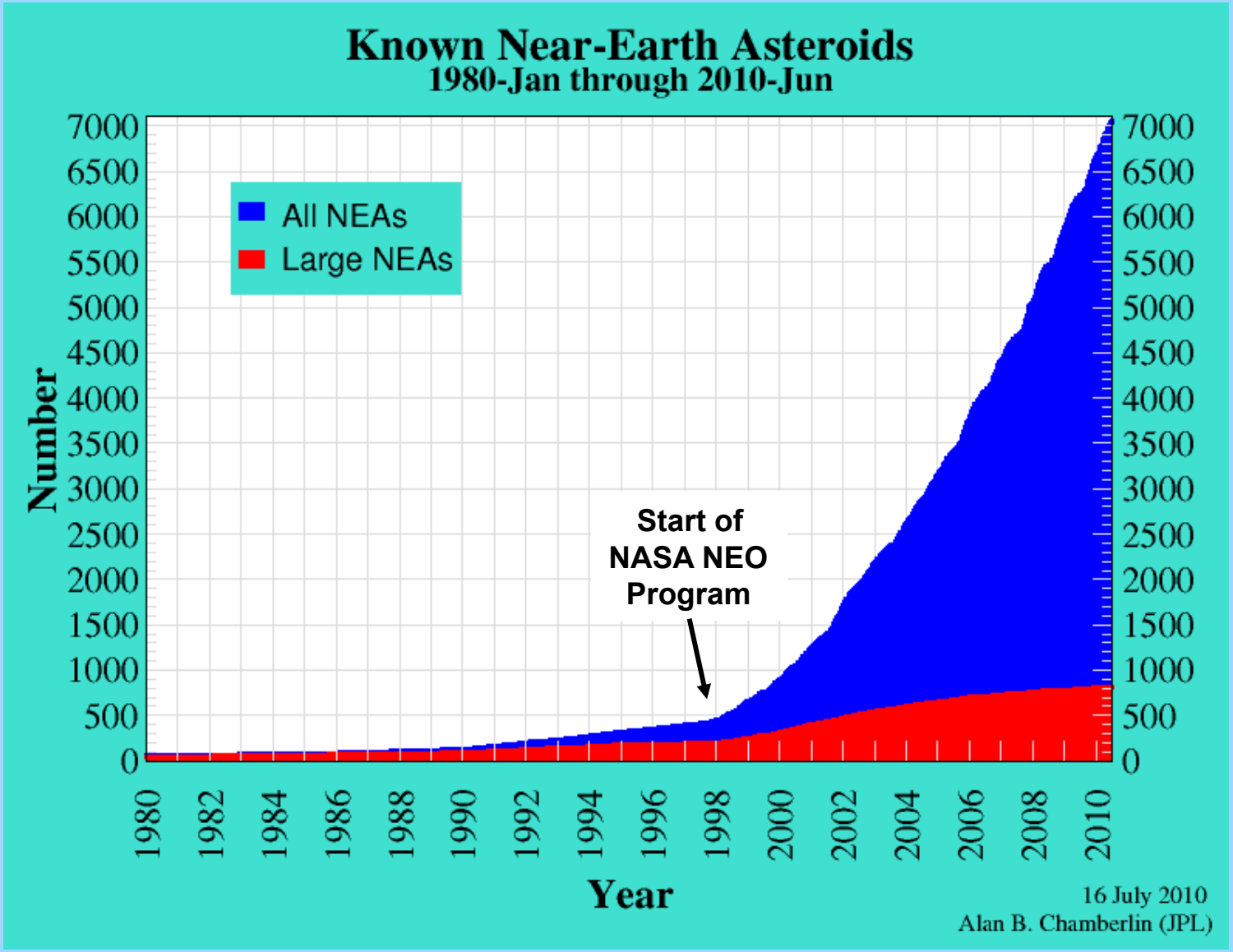
Achieved minimum goal

901*
(86-96%)
as of
8/01/10

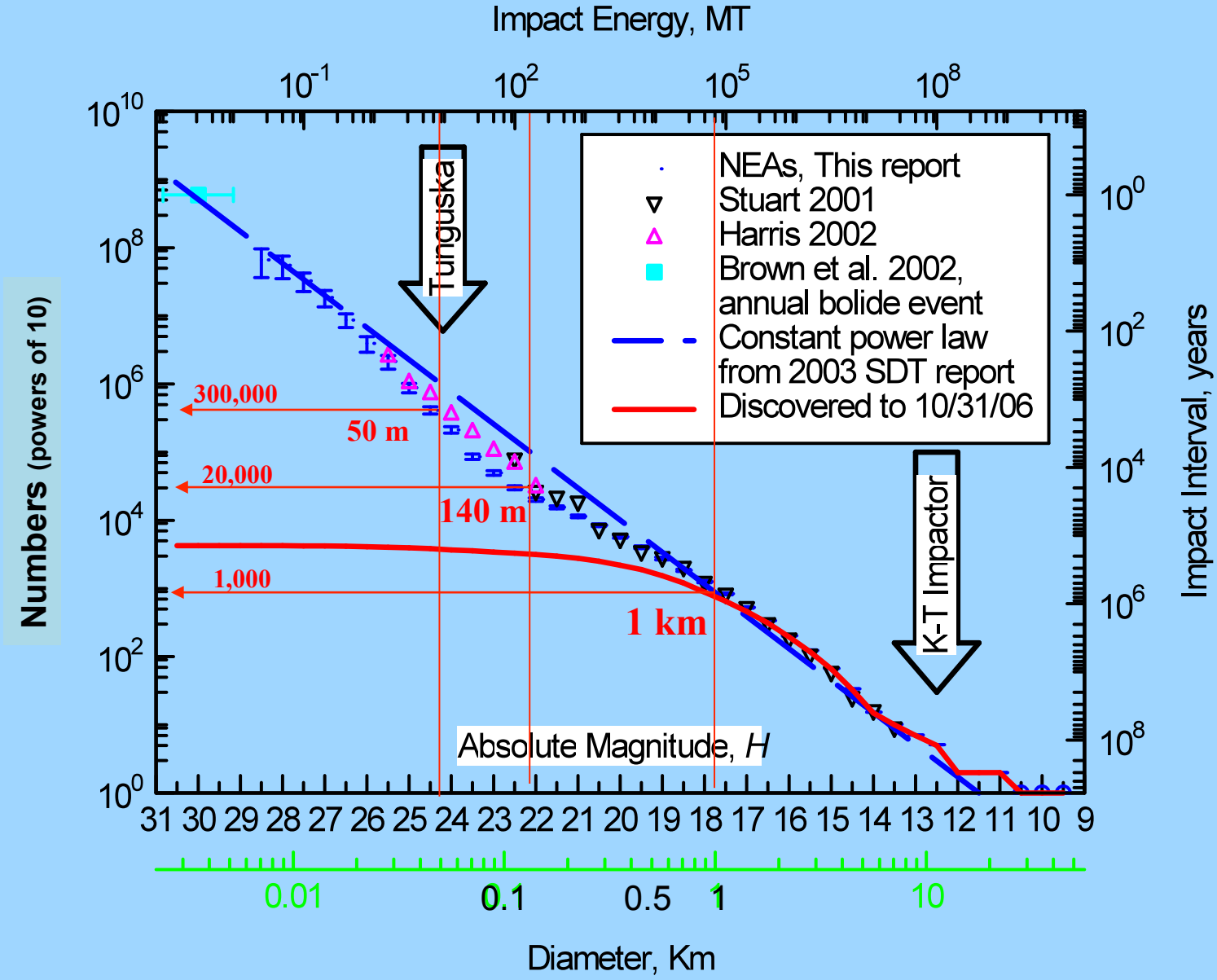
*Includes
85 NECs

6285 smaller objects also found
987 are PHOs

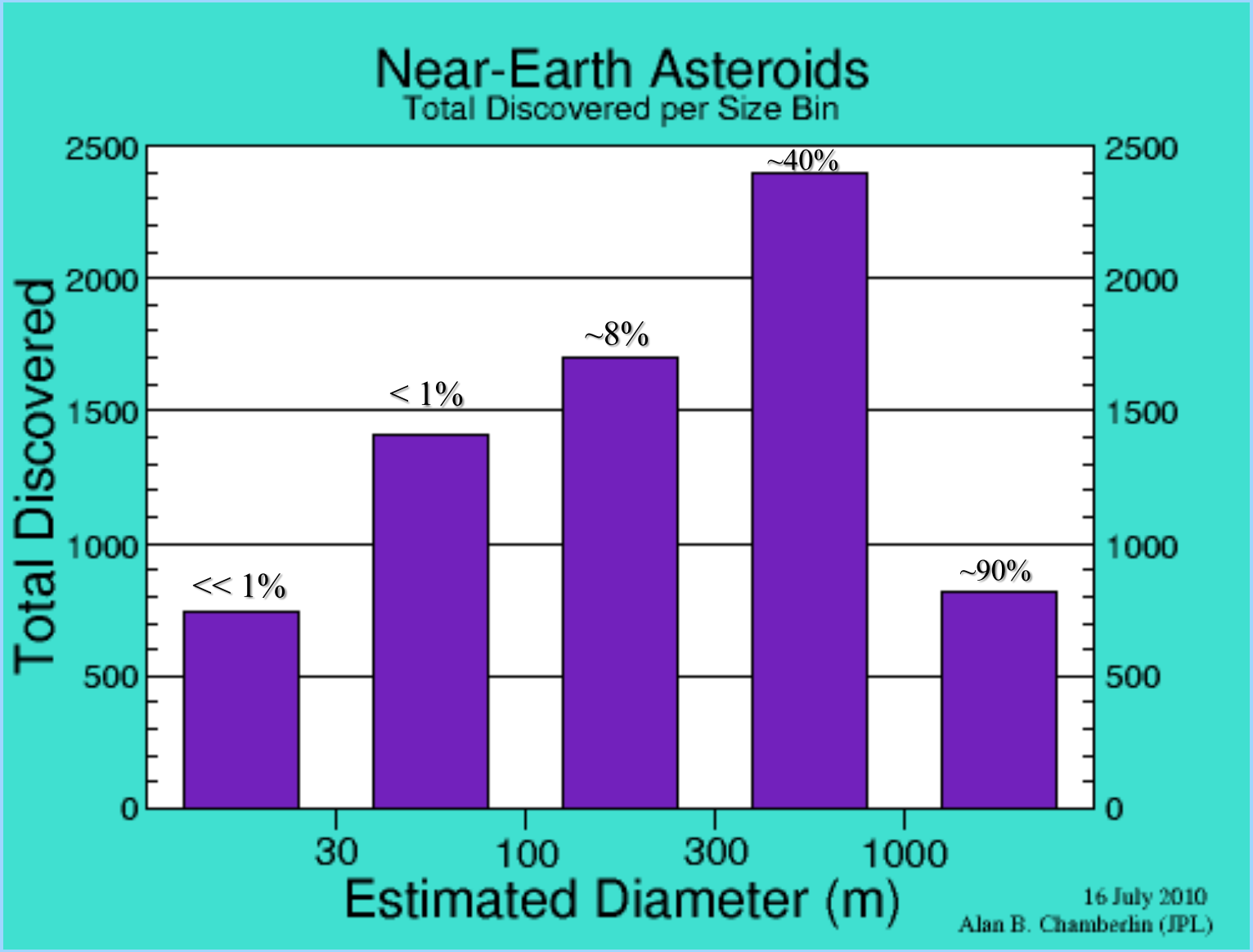
Known Near Earth Asteriod Population



Population of NEAs by Size, Brightness, Impact Energy & Frequency (Harris 2006)



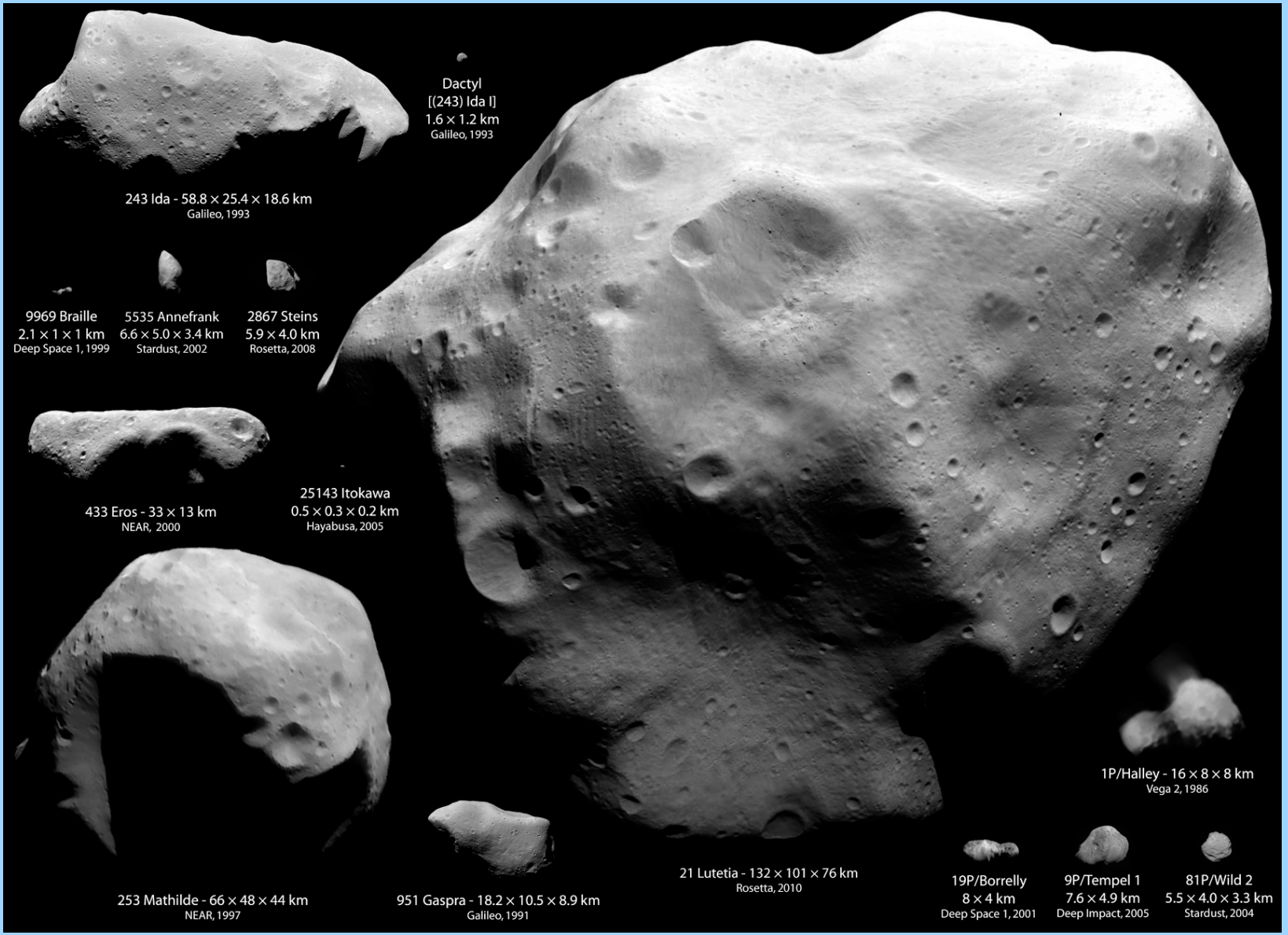
Known Near Earth Asteroid Population



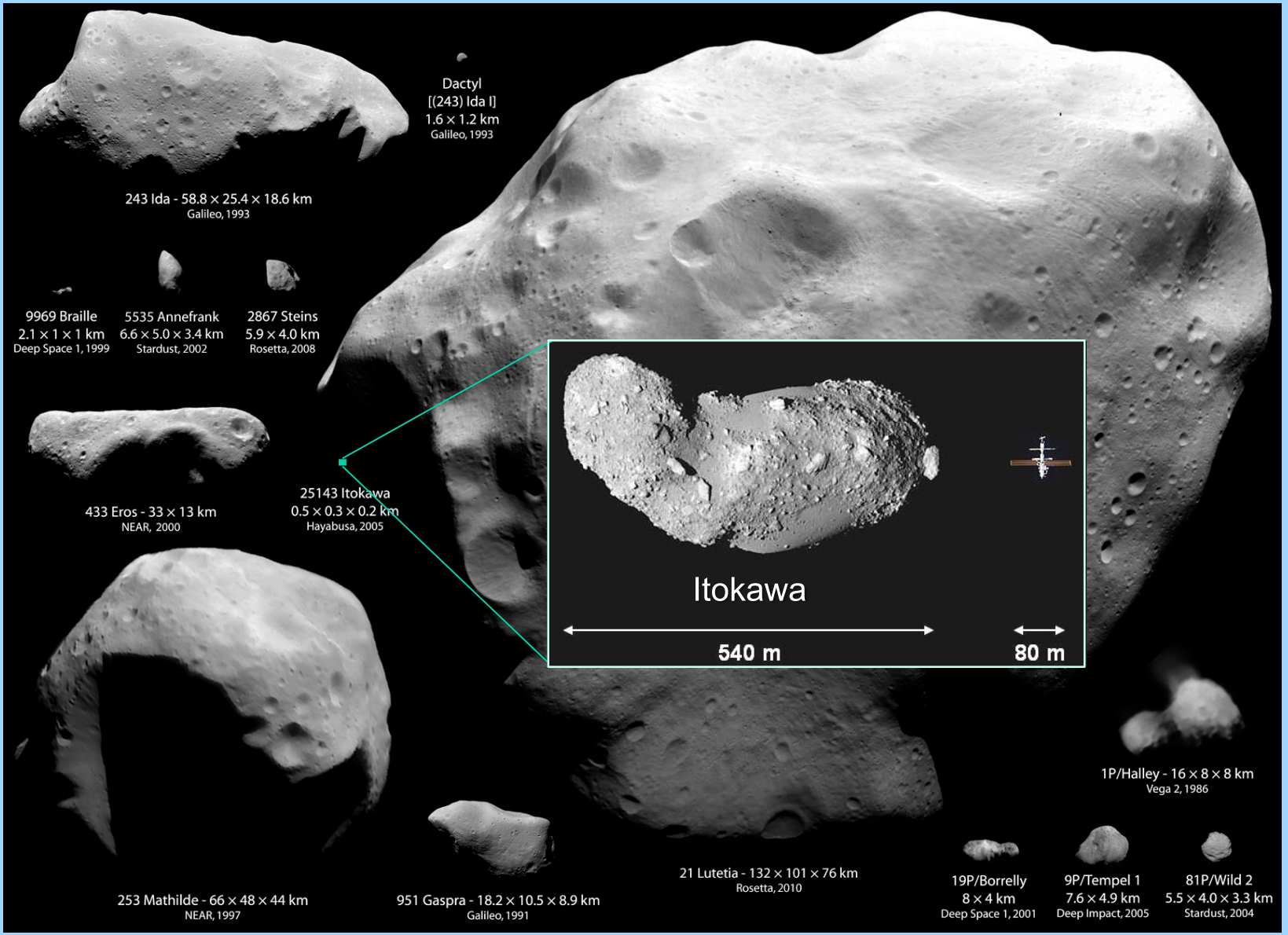
HSF Missions to NEOs

Constraints and Opportunities

Comparing Asteroids



Comparing Asteroids



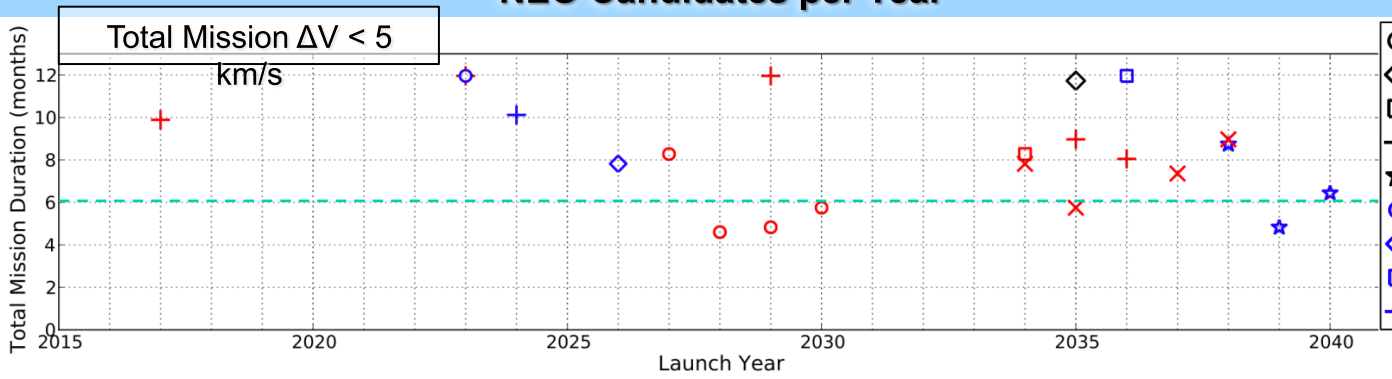
HSF NEO Mission Constraints

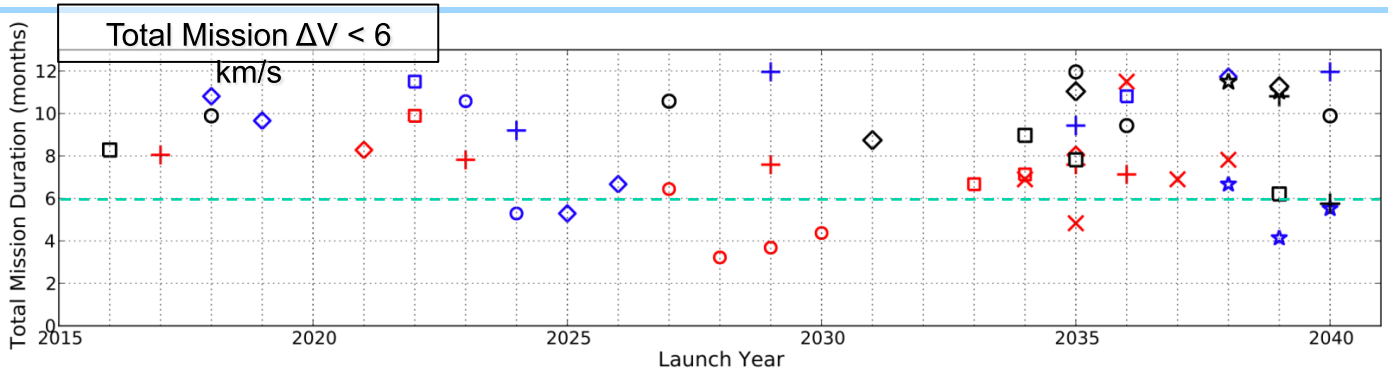
Preliminary outline of possible constraints for human mission success and safety:

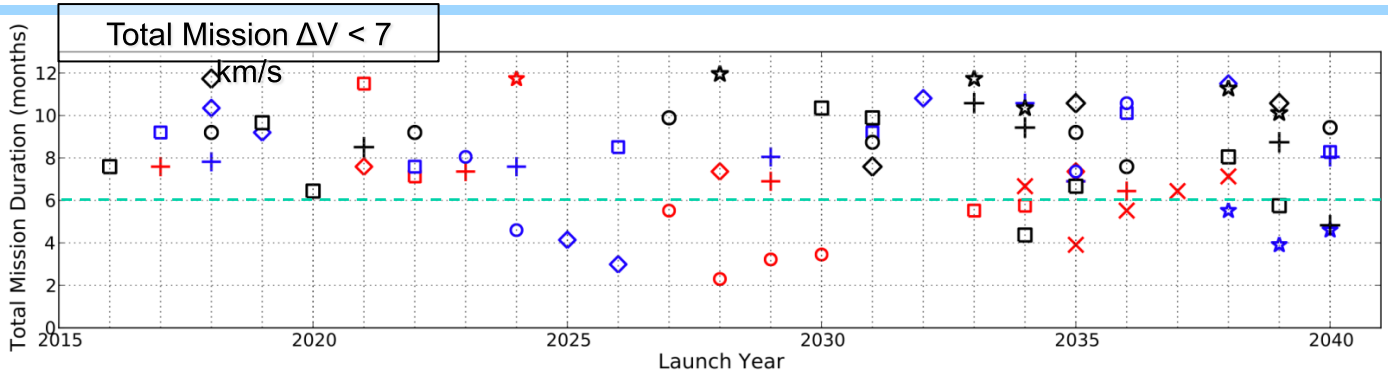
- Accessible with projected capability (~Ares-V) = < 7.5 km/sec dV
- Mission less than 180 days round trip (preferred less than 90 days)
- Return entry velocity less than 12 km/sec
- Greater than 50 meter sized object
- Object in simple axis, slow rotation
- Accessible by robotic precursor mission at least 3 years prior to crew launch

Cx 2-12 Month NEO Piloted Mission Study of 2008

NEO Candidates per Year







NEO Candidates

1996 XB27	2001 FR85
1998 HG49	2000 SG344
2001 BB16	2007 TF15
2003 SM84	1999 CG9
2000 AE205	1993 HD
2001 QJ142	2005 ER95
1999 AO10	2006 BZ147
2008 BT2	2006 QQ56
2008 CX118	

Object Size: > 100m
Object Size: 50m – 100m
Object Size: 25m – 50m
Object Size: < 25m not shown

Piloted Missions

All missions < 12 months
Stay Time > 14 days

Total Mission ΔV includes :

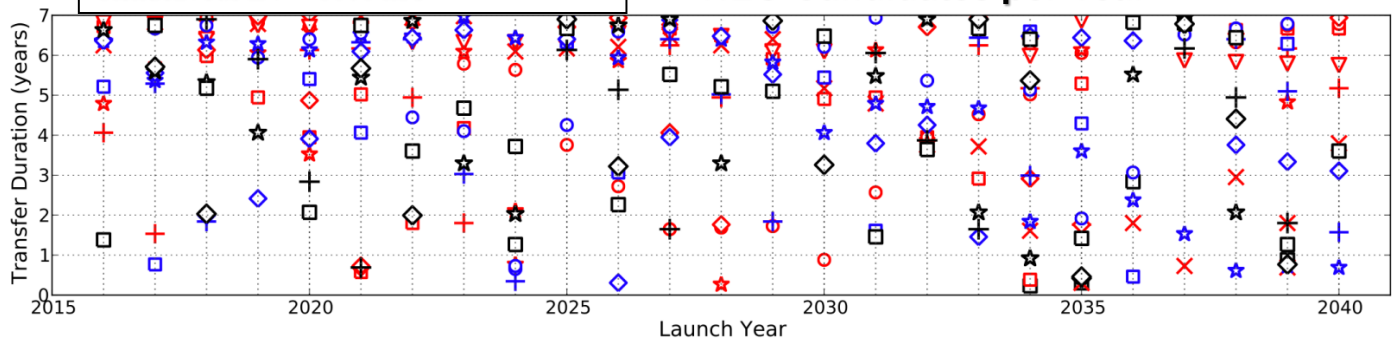
- Earth departure from 185 km circular orbit,
- NEO rendezvous, and
- NEO departure.

NEO Robotic Precursor Missions

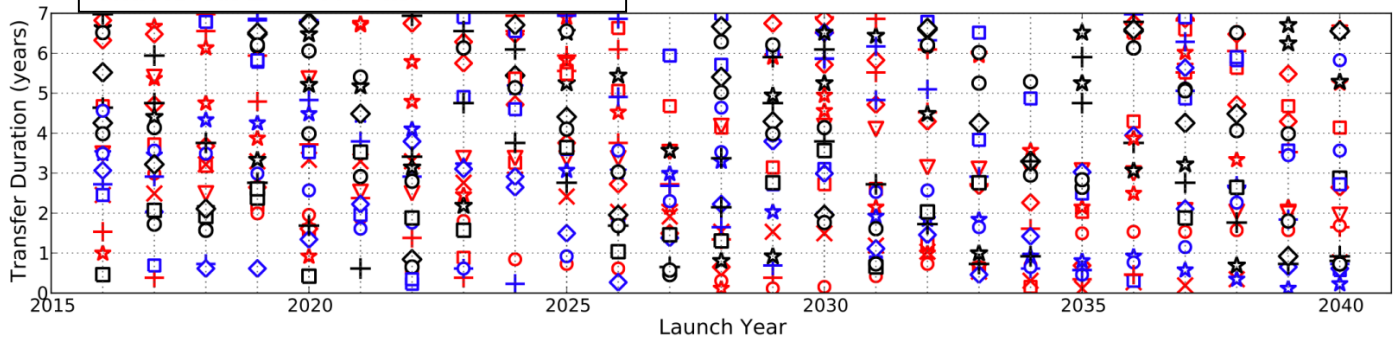
Numerous robotic precursor mission opportunities exist to the same NEOs

Rendezvous ΔV < 1000 m/s

NEO Candidates per Year



Rendezvous ΔV > 1000 m/s



NEO Candidates

1996 XB27	2001 FR85
1998 HG49	2000 SG344
2001 BB16	2007 TF15
2003 SM84	1999 CG9
2000 AE205	1993 HD
2001 QJ142	2005 ER95
1999 AO10	2006 BZ147
2008 BT2	2006 QQ56
2008 CX118	

Object Size: > 100m
Object Size: 50m – 100m
Object Size: 25m – 50m
Object Size: < 25m not shown

Robotic Missions

All missions < 7 years
Total Mission ΔV < 5 km/s

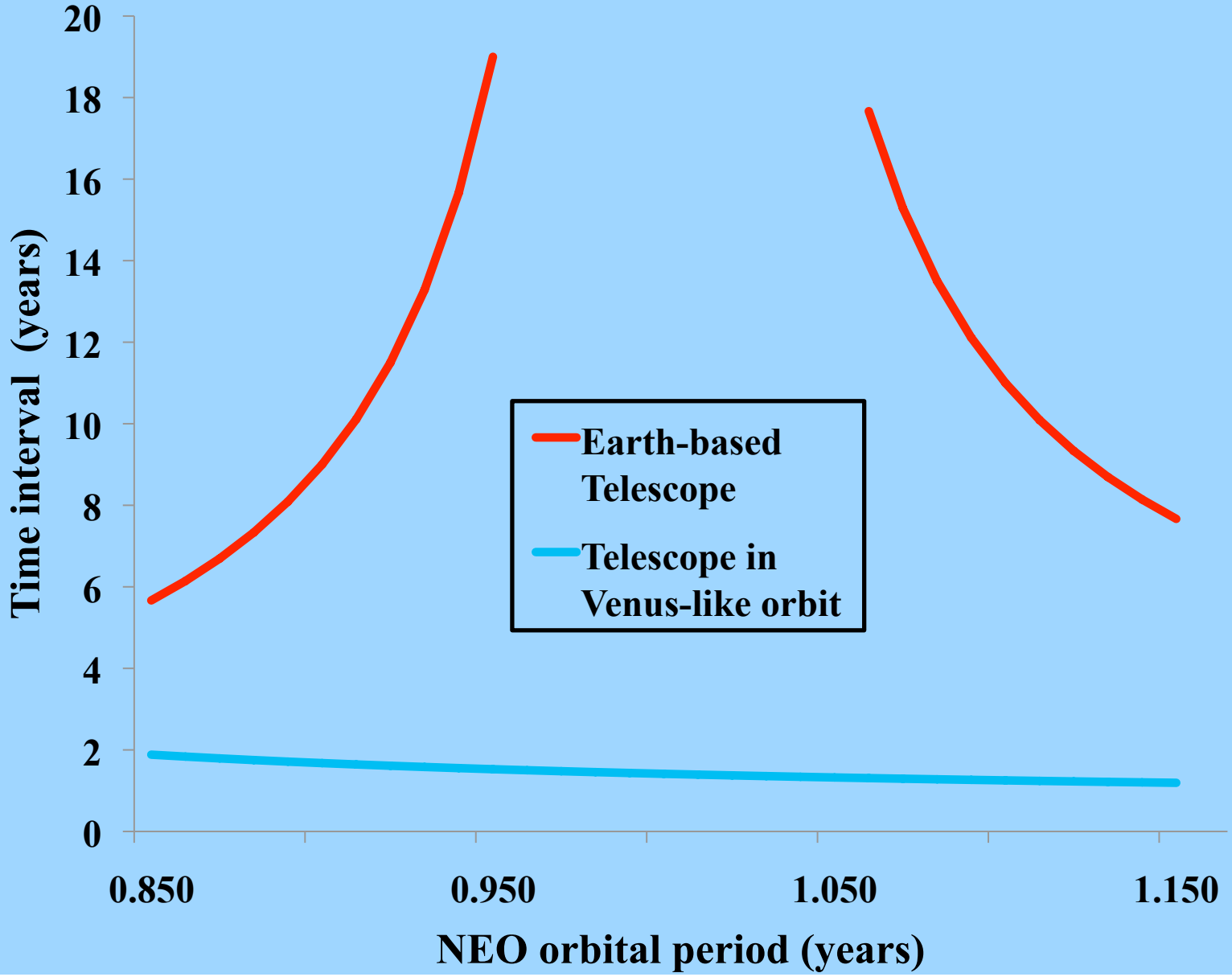
Total Mission ΔV includes :
- Earth departure from 185 km circular orbit
- NEO rendezvous

Current NEO Target Assessment

- Currently, 44 known objects in human mission accessible orbits, assuming ~ Ares-V like capability
- But 27 objects are smaller than 50 meters in size, leaving 17
  - Of 17, 15 are accessible in the 2020 to 2050 timeframe
- However, only 3 have mission durations of less than 180 days
- But we know little about any of these beyond orbit and rough size
  - Nothing known on spin state, composition or possible companion objects

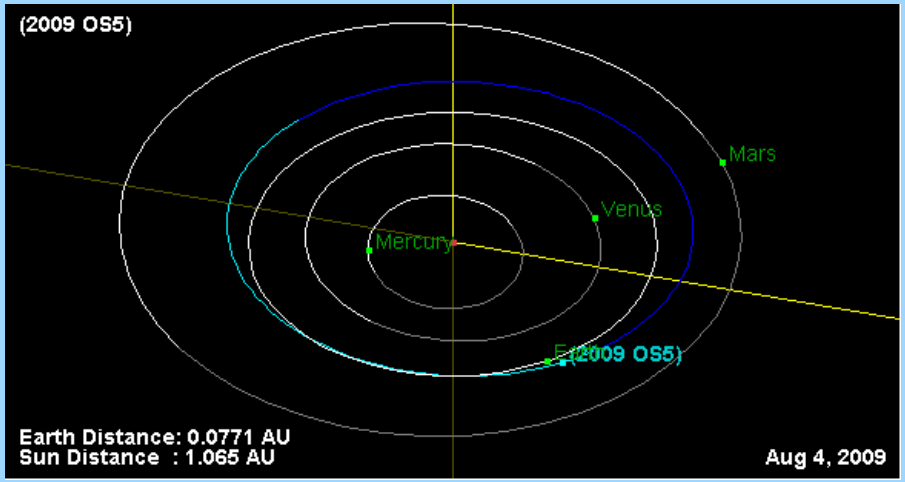
Target	Estimated Size	Launch Date	Mission duration	Last Obs	Next Obs
2009 OS5	~60 m	Mar 11, 2020	170 days	Sep '09	Apr '20
1999 AO10	~50 m	Sep 19, 2025	155 days	Feb '99	Jan '26
2009 OS5	~60 m	Mar 01, 2036	180 days	Sep '09	Apr '20
2003 SM84	~100 m	Mar 22, 2046	180 days	Sep '09	Dec '15(?)

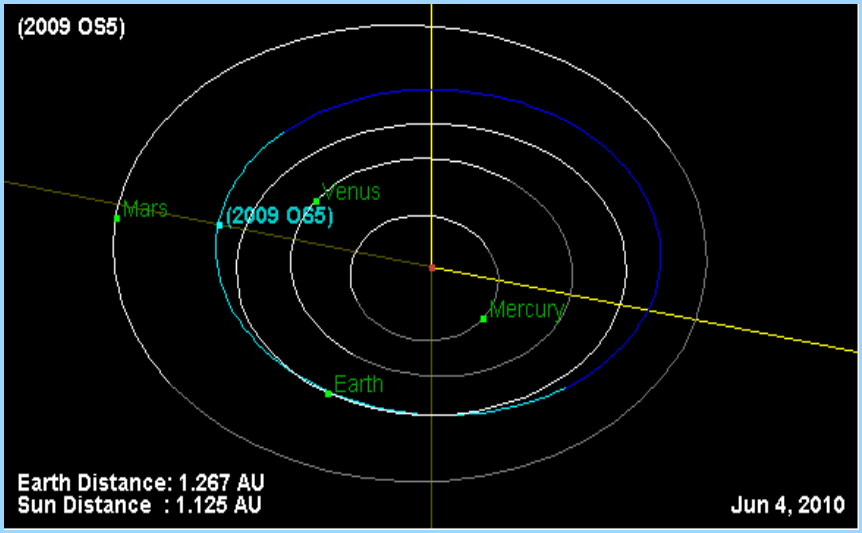
Interval Between Potential Observations

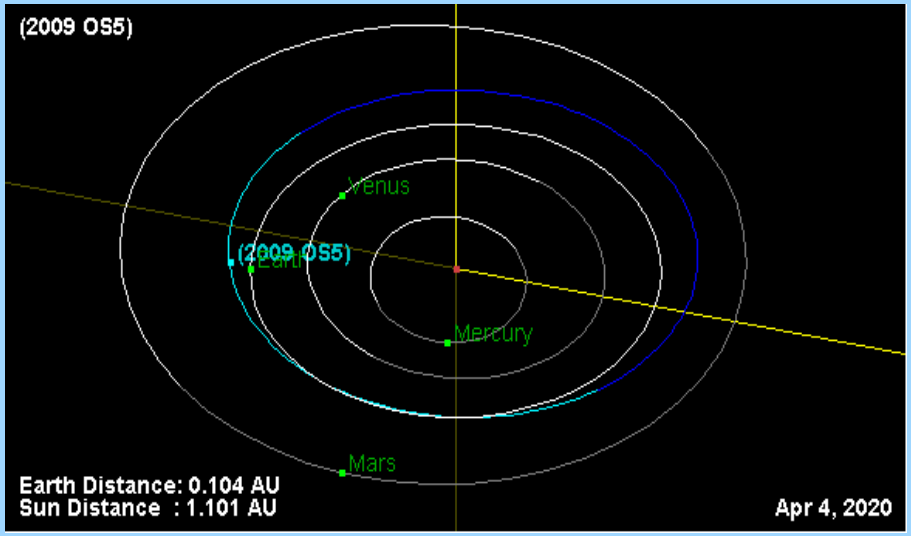


Small Objects & Synodic Periods

- Objects < 100 meters observed only when within ~ 10 million miles of Earth
- Using only ground-based assets, next observation must wait for synodic period
- For small objects, this ~ equals the time of launch opportunity
- 2009 OS5 discovered Aug 2009
- Next opportunity to observe Apr 2020

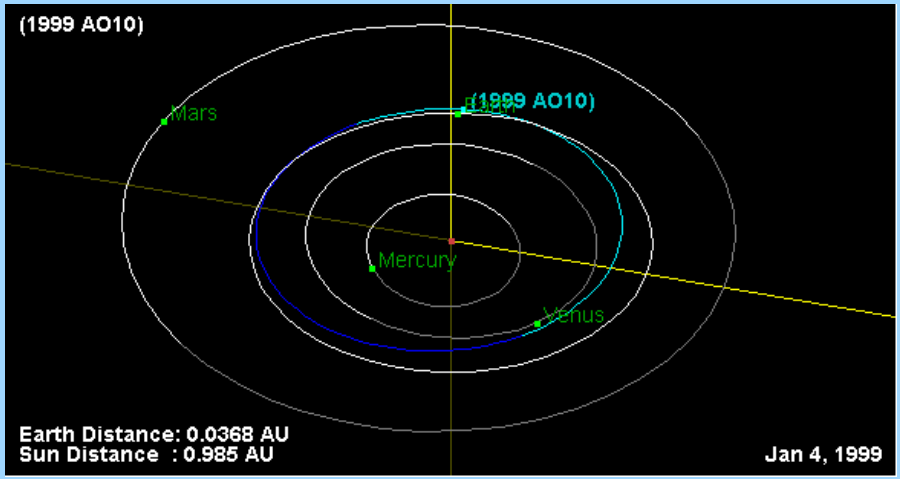


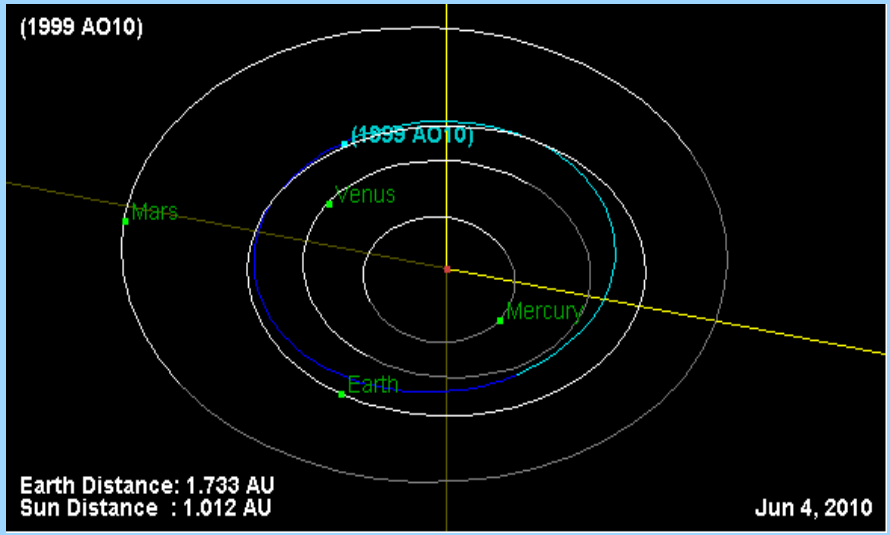


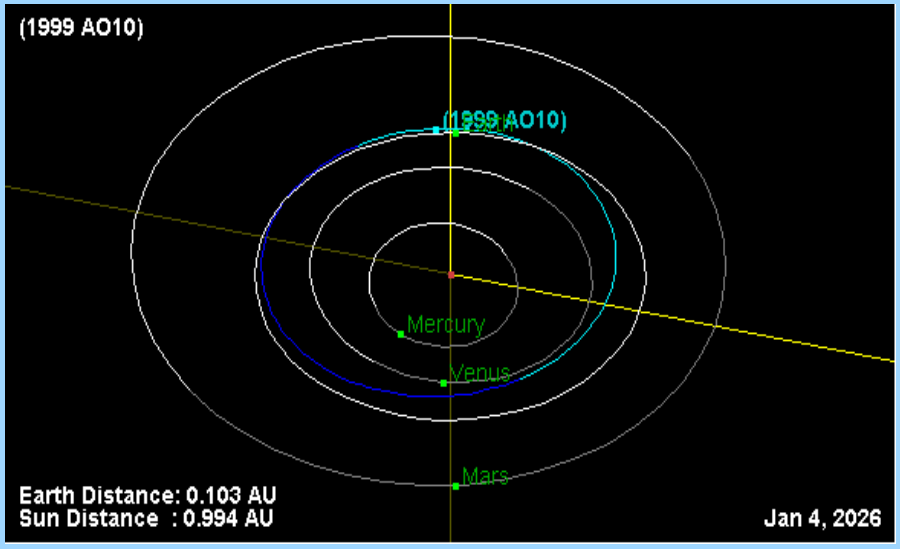


Small Objects & Synodic Periods

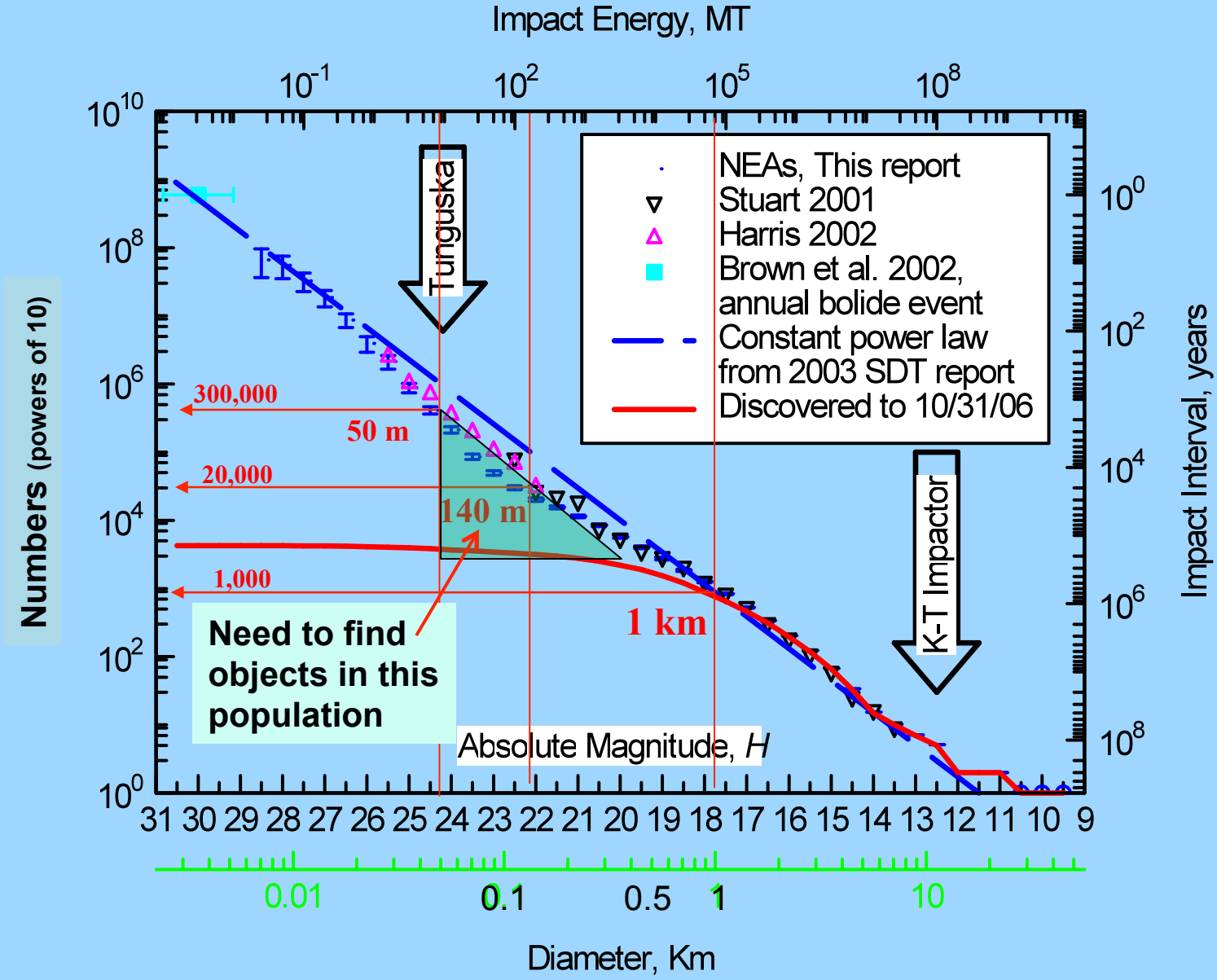
- Similar situation with 1999 AO10
- Discovered Jan 1999
- Not seen since
- Next relative close approach is in 2012-2013, but very poor sun angle
- Next clear opportunity to observe is Jan 2026, just after launch opportunity







Population of NEAs by Size, Brightness, Impact Energy & Frequency (Harris 2006)



Population estimates

One-way Delta-v	Accessible range in semi-major axis	Accessible range in eccentricity	Accessible range in inclination	Estimated number of NEOs >30 m diameter*
3 km/s	0.789–1.201	<0.168	<5.77°	170
5 km/s	0.664–1.336	<0.251	<9.62°	710

***Based on NEO population studies of Bill Bottke, et al**

"NEOStar" Concept

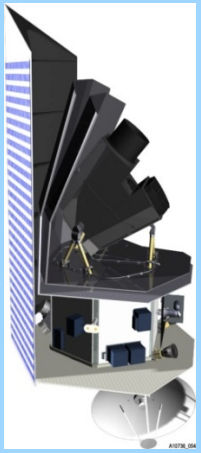
Spitzer

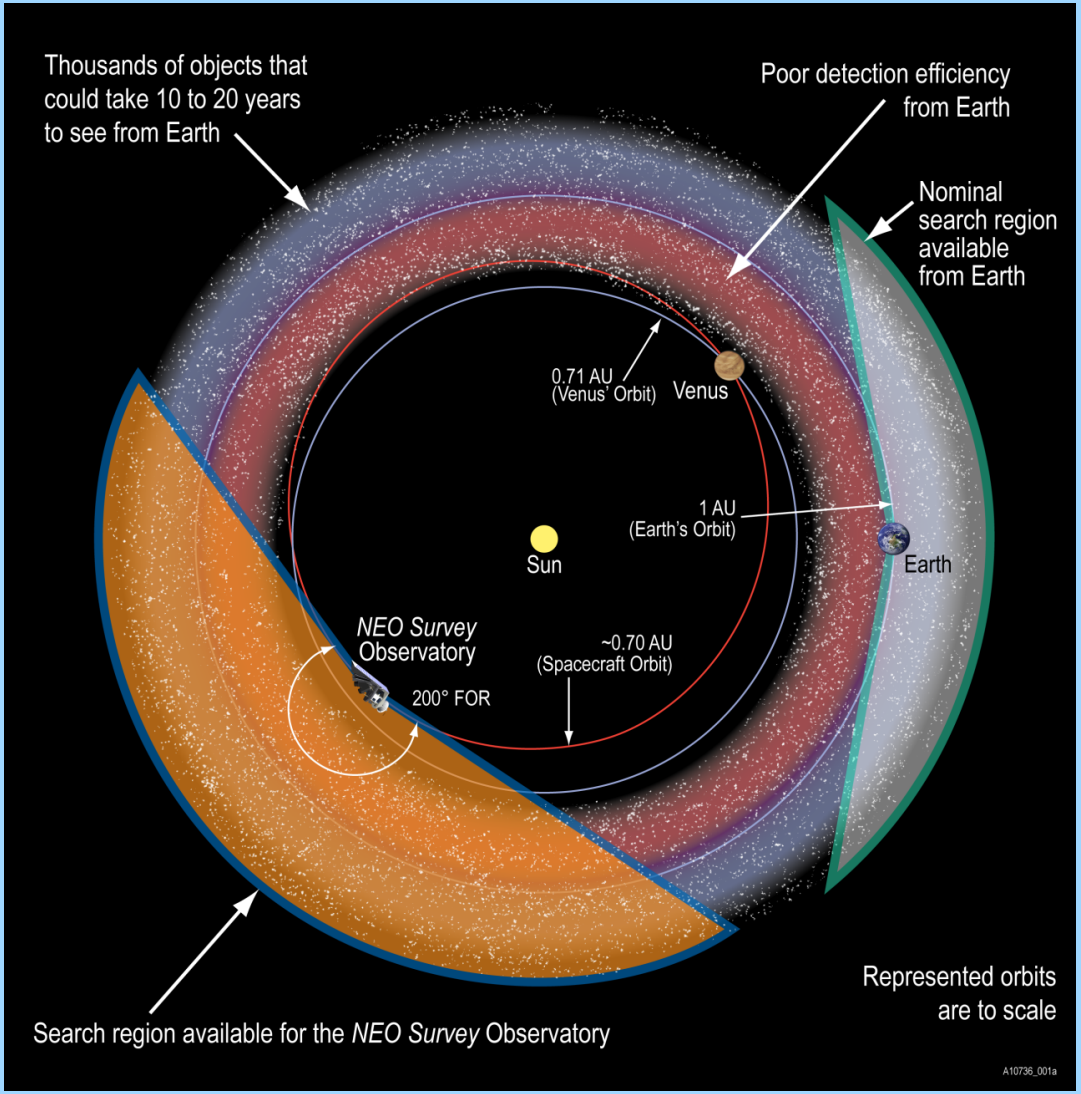
x

Kepler

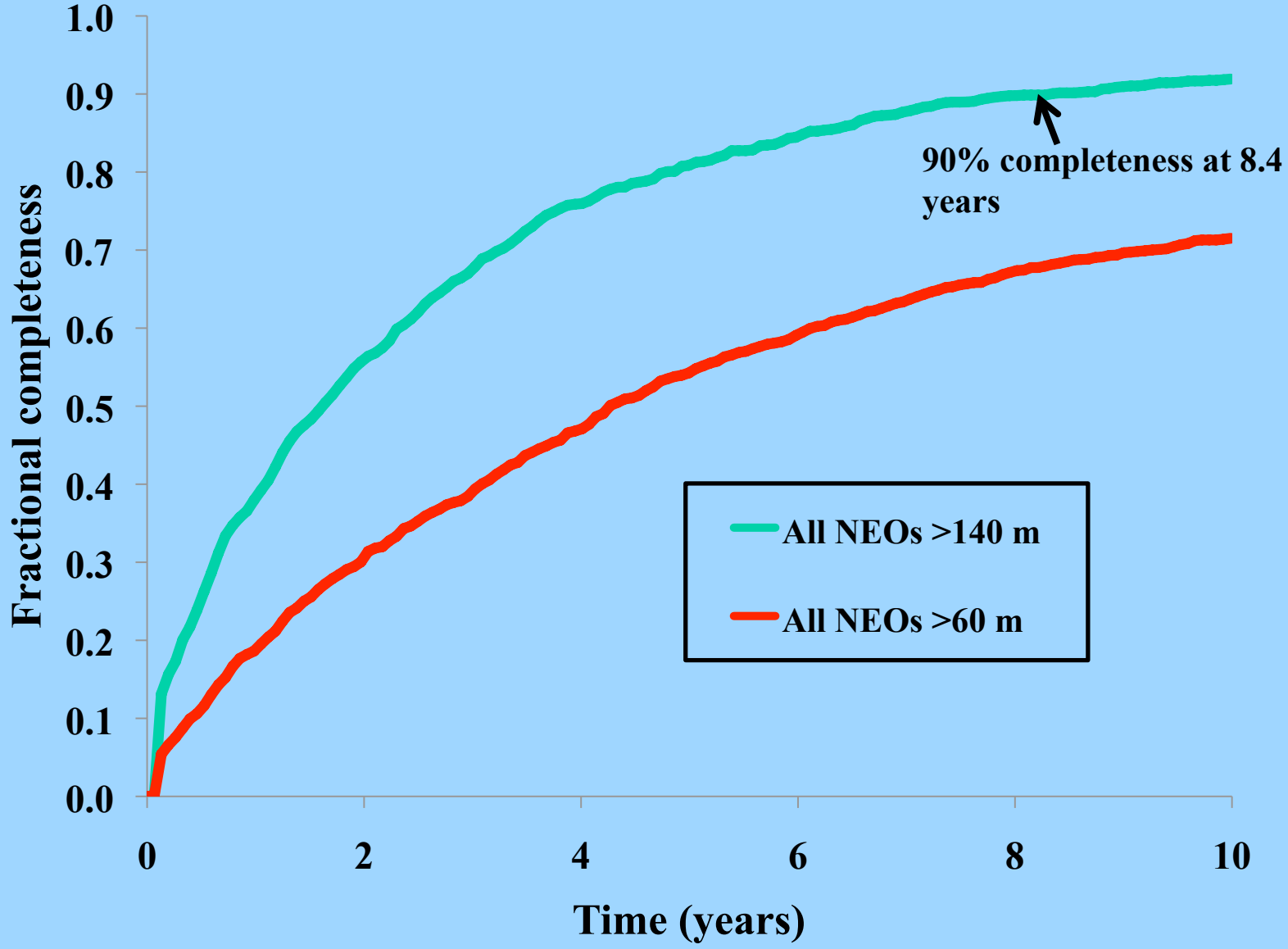
≈

"NEOStar"

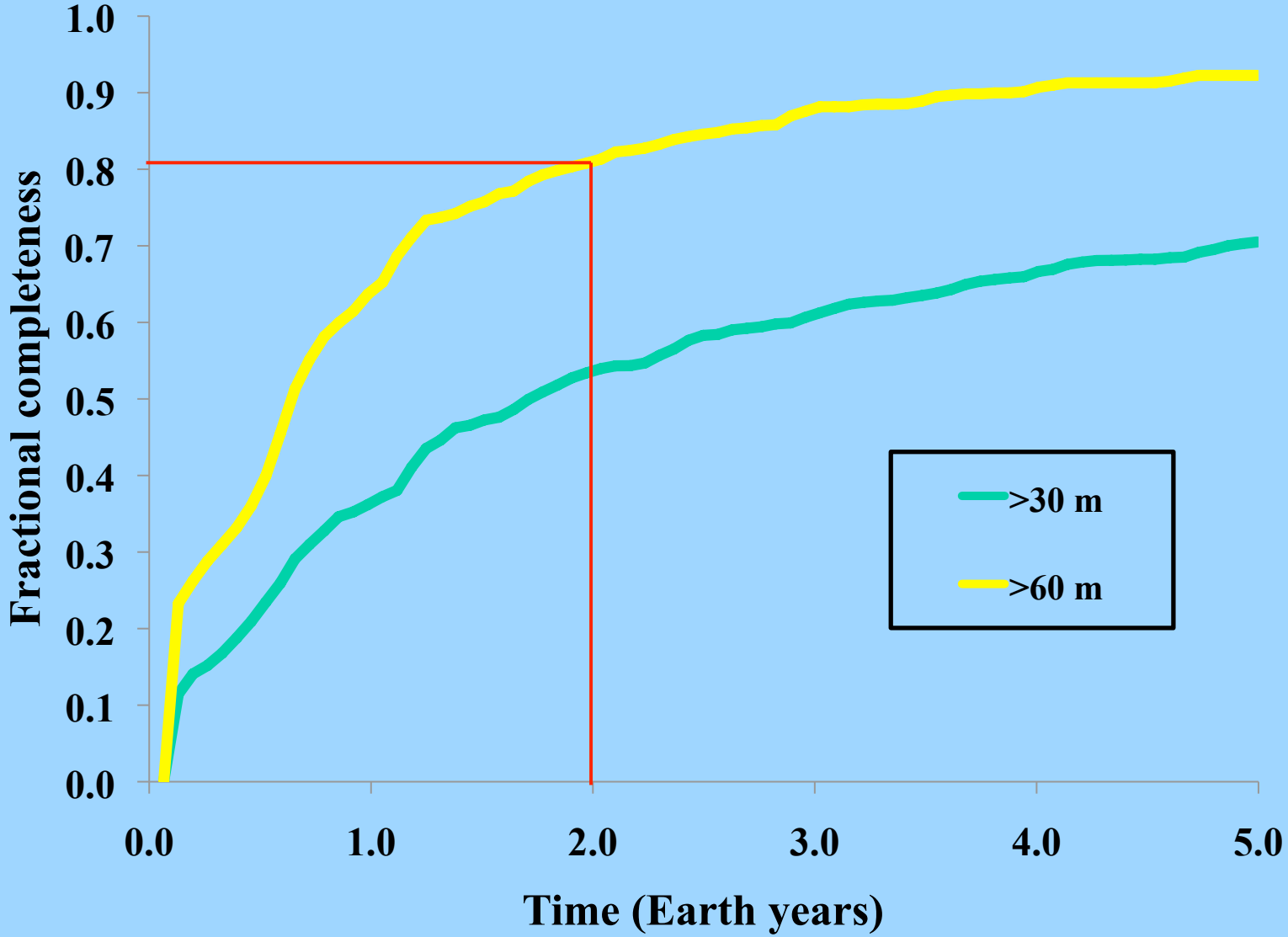




Completeness for entire NEO population: IR space telescope only



Completeness on Human Exploration targets: IR space telescope only



Bottomline:

- For finding Human Exploration targets, a telescope in a Venus-like orbit is the most technically viable option
  - ~400 potential targets from 2 years of observing
- For Planetary Defense (detection & tracking of all PHOs), an IR telescope in a Venus-like orbit speeds up the search by a decade